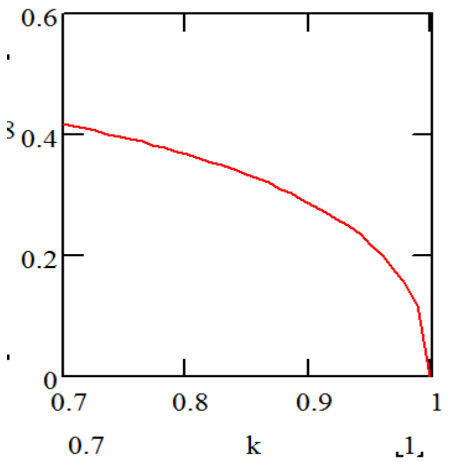

Figure 1- Graph of change of efficiency of autonomous power supply from degree of compression

Conclusions. From the analysis of the graph it should be noted the hyperbolic dependence of the change in the efficiency of the autonomous power source on the ratio of currents.

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THERMODYNAMIC METHOD FOR DIAGNOSIS OF THE PUMP

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Annotation. *Thermodynamic method for diagnosing the proposed package, which is more incorrectly characterized by physically second changes, the absence of energytransformations occurring at the port pump, estimated by the indirect intensity. This parameter provides the most important informationcharacterization of the general technicalrequirementspumps recommended for rapid diagnosis.*

Keywords:*pump, diagnostics, thermodynamic method, internality, exergy, entropy, enthalpy, idealadiabatic process.*

Анотація.*Пропонуєтьсятермодинамічнийспосібдіагностуваннянасоса, якийнайбільшкоректнохарактеризуєфізичнотермодинамічнусутьперетвореньенергіївпротoчнійчастинінасоса, щооцінюютьсяйоговнутрішнімККД. Даний параметр найбільш інформативно характеризує загальний технічний стан насоса і рекомендується для його експрес-діагностування.*

Ключові слова: *насос, діагностування, термодинамічний метод, внутрішній ККД, ексергія, ентропія, ентальпія, ідеальний адіабатичний процес.*

Introduction. Pumping installations have wide application in the national economy: all industries, water utilities, land reclamation, communal facilities, etc. Therefore, there are urgent measures to ensure the reliability and cost effectiveness of their operation are . One of these measures is to diagnose pumps for the purpose of establishing their technical condition and for the purposeful prevention, inspection and repair. The well-known method for technical diagnostics of the pump is stat parametric method, which is more commonly used in stationary diagnostic laboratories (after pump repair). To date, the built-in technical diagnostics are most important and relevant, even express diagnostics, which are compact, inexpensive for mass use. They can constantly monitor the parameters of the pump's operation and instantly fix their deviations from the reference values.

Aim. The purpose of the work is to establish certain most informative parameters of the pump system operation and to establish a correlation between the changes in these parameters and the corresponding changes in the technical condition of the pump, its reliability indicators.

Materials and methods. It is proposed to use the thermodynamic method of analysis of the transformations of mechanical energy into energy of the hydraulic flow of the pump. This energy principle of diagnosing the current part of the pump on the energy input-output most significantly characterizes the efficiency of the installation in accordance with its purpose and additionally informs about the cost-effectiveness of this conversion process.

Results. There are energy losses that can logically be estimated from the efficiency, as the flowing part of the pump is the conversion of mechanical energy into the energy of hydraulic flow. There are no direct meters of efficiency, and its value is calculated. It is known [1] that it is customary to divide energy losses into a pump into three components: hydraulic, volumetric and mechanical, which are estimated by the respective efficiency.

$$\eta = \eta_2 \cdot \eta_0 \cdot \eta_м , \tag{1}$$

The energy losses in the flowing part of the pump are fully estimated $\eta_2 i \eta_0$ and mechanical losses $\eta^1_м$ (except energy losses in the pump bearings). That is, the internal efficiency of the pump

Втратиенергії, яківідбуваютьсявпроточнійчастинінасосаповністюоцінюються $\eta_2 i \eta_0$, амеханічнічастково $\eta^1_м$ (крімвтратенергіївпідшипникахнасоса). Тобто, внутрішнійККДнасоса

$$\eta_w = \eta_2 \cdot \eta_0 \cdot \eta m , \tag{2}$$

All internal energy losses in the pump are converted to heat, transported by the flow of water through the pump and manifest themselves in the difference in water temperatures Δt between the outlet and inlet nozzles of the pump. The magnitude of this temperature difference is estimated by the internal efficiency of the pump and characterizes the quality of its functioning as an energy converter.

The presence of the temperature difference Δt itself is correctly confirmed $i - S$ by the diagram (Fig. 1), which shows the thermodynamic essence of physical energy transformations in the flowing part of the pump. Points 1 and 2 show the energy state of the fluid at the inlet and outlet of the pump, and lines 1-2 represent the actual thermodynamic process of converting energy into the pump. Line 1-3 - reflects the possible ideal process of adiabatic fluid compression without heat exchange with the environment. Exergy process [2]

$$e = (i - i_0) - T_0(S - S_0), \tag{3}$$

where i, i_0, S, S_0 – instantaneous and initial values of enthalpy and entropy;
T_0 – starting temperature.

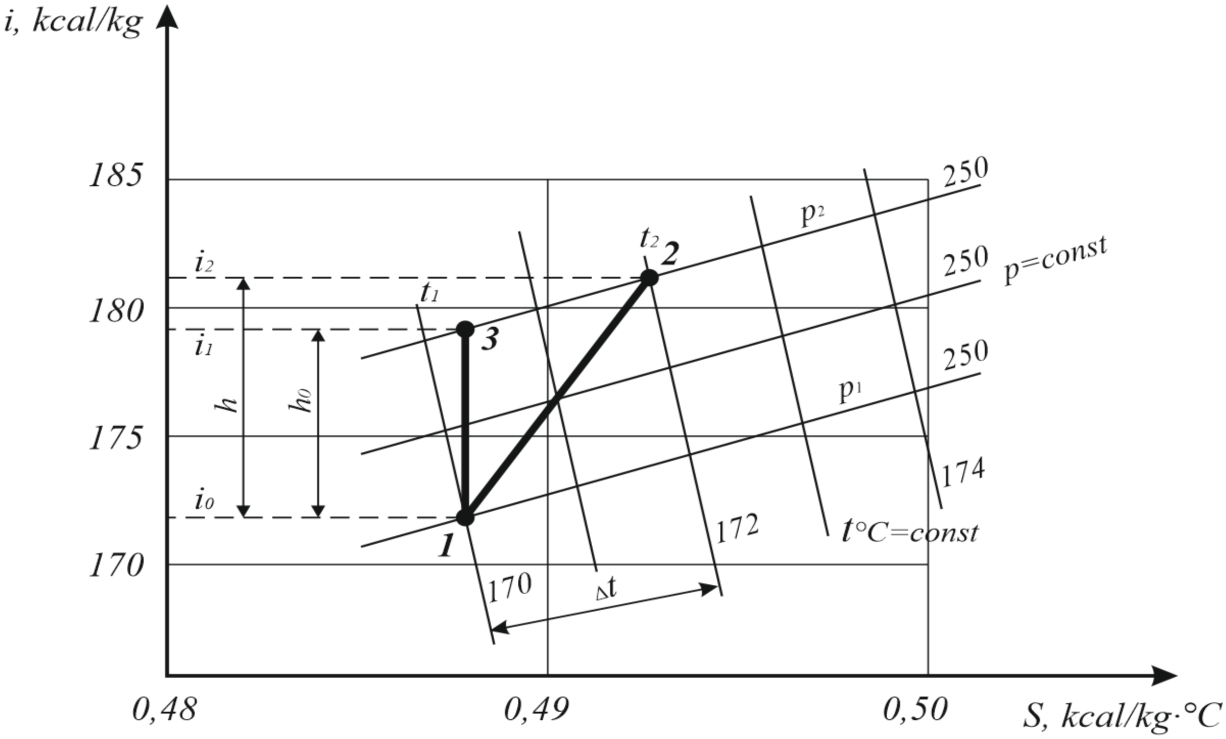

Figure 1 - The presence of the temperature difference

We mean by the internal efficiency of the pump a ratio as the increaseheat capacity of the h0 medium, which can be pumped with an adiabatic increase in the pressure, per the actual heat capacity of the h (fig. 1)

$$\eta_в = \frac{h_0}{h} = \frac{h_0}{h_0 + \Delta h} = \frac{1}{1 + \Delta h / h_0}, \tag{4}$$

where Δh – losses of specific heat, which are manifested in the temperature difference Δt .

The amount of heat is released into the pump

$$\Delta Q^- = 0{,}24 \cdot \Delta N, \tag{5}$$

where - ΔN losses of power in the pump.

On the other hand, the amount of heat that is delivered by the flow of water from the pump

$$\Delta Q^- = \rho \cdot Q_p \cdot c \cdot \Delta t, \tag{6}$$

where - ρ – the density of the water; Q_p – pump performance; c – specific heat of water.

Pump power losses can be showed by the internal efficiency of the pump and its operating hydraulic power N_p.

$$\Delta N = N_p(1/\eta_в - 1) = \rho g Q_p H_p(1/\eta_в - 1) \quad (7)$$

whereH_p – working pressure of the pump.

If wewill equate (5) i (6) ($\Delta Q^+ = \Delta Q^-$) and consider (7), then weget the endresult.

$$\eta_в = \frac{1}{1 + \dfrac{c \cdot \Delta t}{0{,}24\ g \cdot H_p}}. \quad (8)$$

Thus, the internal efficiency of the pump can be calculated from the data Δt and H_p, and the technical condition of the pump can be determined by comparing this value with its permissible values.

It should be noted that the internal efficiency of the pump (8) is independent of the density of the fluid, which is a significant advantage of this method for diagnosing of the pump, as temporary contamination of the fluid will not be perceived as a change in the technical condition of the pump.

The second important factor is the automatic identification in (8) of the temperature difference Δt across the H_p that reaches the pump. The different temperature differences Δt will be recorded at different H_p pressures of the same pump. As the pressure Hp increases, the differences will increase simultaneously, and their ratio will become constant, which corresponds to one technical condition of the flowing part of the pump. That is, the changes Δt do not yet indicate changes in the technical condition of the pump, whether or not the pressure of the pump Hp is important at the same time H_p. If H_p.= const, the changes Δt indicate changes (wear) of the flowing part of the pump.

In addition, the correctness of the dependence (8) is also confirmed for the case of a perfect pump– without energy lossesthen $\Delta t = 0$, and based on (8) -$\eta_в = 1$. Inothercases, when $\Delta t > 0$, efficiency of the pump is $\eta_в < 1$.

Conclusions. The energy losses and their estimation through the internal efficiency of the pump most characteristically reflect the efficiency of energy transformations in the flowing part of the pump in accordance with its purpose. This parameter of the pump operation is the most informative and correctly reflects the technical status and can be recommended for rapid diagnostics of the pump.

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